CLAIMS

What is claimed is:

1. A water-gas shift reactor system comprising:

a first stage water-gas shift reactor receiving a reformate gas, said first stage reactor including a catalyst that converts carbon monoxide and water to carbon dioxide and hydrogen;

a heat exchanger receiving the reformate gas from the first stage reactor, said heat exchanger cooling the reformate gas, said heat exchanger including a catalyst that converts carbon monoxide and water to carbon dioxide and hydrogen; and

a second stage water-gas shift reactor receiving the cooled reformate gas from the heat exchanger, said second stage reactor including a catalyst that converts carbon monoxide and water to carbon dioxide and hydrogen.

2. The system according to claim 1 wherein the heat exchanger is selected from the group consisting of a tube and fin heat exchanger, a tube and shell heat exchanger and a bar and plate heat exchanger.

3. The system according to claim 1 wherein the catalyst is selected from the group consisting of precious metals, Fe_3O_4/Cr_2O_3 and CuO/ZnO.

4. The system according to claim 1 wherein the first and second stage reactors are medium temperature water/gas shift reactors that operate in the 300-400°C range.

5. The system according to claim 1 wherein the first stage reactor is a high temperature reactor operating in the 400-500°C range and the second stage reactor is a low temperature reactor operating in the 200-280°C range.

6. The system according to claim 1 wherein the water-gas shift reactor system is part of a fuel processing system for producing hydrogen for a fuel cell.

7. The system according to claim 6 wherein the water-gas shift reactor system is positioned between a primary reactor and a preferential oxidation reactor in the fuel processing system.

8 The system according to claim 1 wherein the reformate gas enters the first stage reactor at a temperature of about 300°C enters the heat exchanger at a temperature of about 370°C, enters the second stage reactor at a temperature of about 310°C and exits the second stage reactor at a temperature of about 315°C.

9. The system according to claim 8 wherein the heat exchanger uses air, steam or liquid water to cool the reformate gas.

10. The system according to claim 9 wherein the air enters the heat exchanger at ambient temperature and exits the heat exchanger at about 360°C.

11. A heat exchanger for cooling a main fluid, said heat exchanger comprising:

an inlet for receiving a cooling fluid;

an internal structure through which the cooling fluid and the main fluid propagate, said structure including a catalyst that converts carbon monoxide to carbon dioxide in the main fluid; and

an outlet through which heated cooling fluid exits the heat exchanger.

12. The heat exchanger according to claim 11 wherein the main fluid is a reformate gas flowing in a hydrogen fuel processing system.

13. The heat exchanger according to claim 12 wherein the heat exchanger is positioned between a primary reactor and a water-gas shift reactor in the fuel processing system.

14. The heat exchanger according to claim 12 wherein the heat exchanger is positioned between a water-gas shift reactor and a preferential oxidation reactor in the fuel processing system.

15. The heat exchanger according to claim 12 wherein the heat exchanger is positioned within a water-gas shift reactor assembly in the fuel processing system.

16. The heat exchanger according to claim 15 wherein the heat exchanger is positioned between a first stage reactor and a second stage reactor.

17. The heat exchanger according to claim 16 wherein the first and second stage reactors are medium temperature water-gas shift reactors operating in the 300-400°C range.

18. The heat exchanger according to claim 11 wherein the catalyst is selected from the group consisting of precious metals, Fe_3O_4/Cr_2O_3 and CuO/ZnO.

19. The heat exchanger according to claim 11 wherein the internal structure is selected from the group consisting of a tube and fin structure, a bar and plate structure and tube and shell heat structure.

20. A fuel processing system for producing a hydrogen reformate gas, said system comprising:

a primary reactor, said primary reactor receiving a liquid hydrocarbon fuel and generating a reformate gas including hydrogen and carbon monoxide;

a first heat exchanger, said first heat exchanger receiving the reformate gas from the primary reactor and cooling the reformate gas;

a water-gas shift reactor assembly including a first stage water-gas shift reactor receiving the cooled reformate gas from the first heat exchanger, a second heat exchanger receiving the reformate gas from the first stage reactor, said second heat exchanger cooling the reformate gas, and a second stage water-gas shift reactor receiving the cooled reformate gas from the second heat exchanger, each of the first stage reactor, second heat exchanger and second stage reactor including a catalyst that converts carbon monoxide and water to carbon dioxide and hydrogen;

a third heat exchanger, said third heat exchanger receiving the reformate gas from the second stage reactor and cooling the reformate gas; and

a preferential oxidation reactor, said preferential oxidation reactor receiving the cooled reformate gas from the third heat exchanger, said preferential oxidation reactor including a catalyst that selectively oxidizes carbon monoxide to carbon dioxide in the reformate gas.

21. The system according to claim 20 wherein one or both of the first and third heat exchangers include a catalyst that converts carbon monoxide and water to carbon dioxide and hydrogen.

22. The system according to claim 20 wherein the first, second and third heat exchangers are selected from the group consisting of tube and fin heat exchangers, bar and plate heat exchangers and tube and shell heat exchangers.

23. The system according to claim 20 wherein the catalyst is selected from the group consisting of precious metals, Fe_3O_4/Cr_2O_3 and CuO/ZnO.

24. A method of cooling a reformate gas in a fuel processing system, comprising:

providing a heat exchanger including a catalyst that converts carbon monoxide and water to carbon dioxide and hydrogen by an exothermic reaction; and

causing the reformate gas to flow through the heat exchanger to be cooled.

25. The method according to claim 24 further comprising positioning the heat exchanger between a first stage water-gas shift reactor and a second stage water/gas shift reactor.

26. The method according to claim 25 wherein the water-gas shift reactors are medium temperature reactors.

27. The method according to claim 24 further comprising positioning the heat exchanger between a primary reactor and a water-gas shift reactor.

28. The method according to claim 24 further comprising positioning the heating exchanger between a water-gas shift reactor and a preferential oxidation reactor.